4D Trajectory Departure Traffic Flow Management Concepts Utilizing User-Preferred Trajectories

Mark Peters
Dave Schleicher
Doug Sweet

Sensis Corporation
85 Collamer Crossings
East Syracuse, New York 13057

Tel: +1 315-445-0550 Fax: +1 315-445-9401
www.sensis.com info@sensis.com

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Detect the Difference

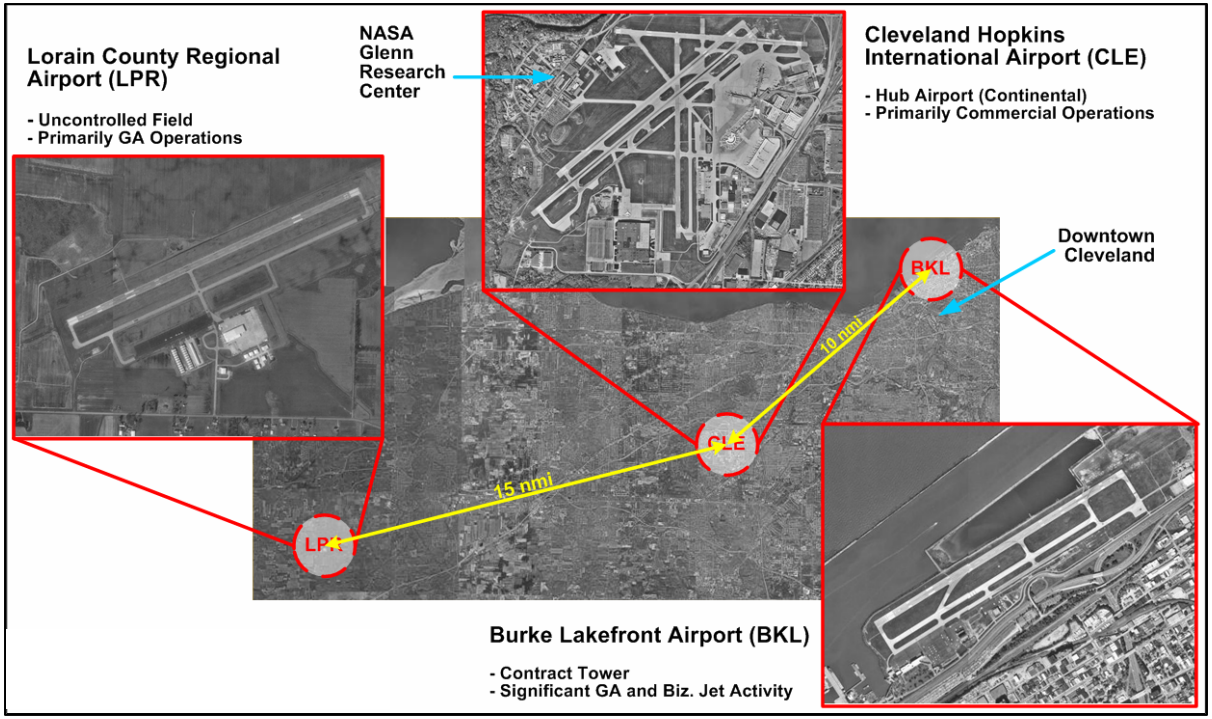
Outline

- **NextGen ATS CNS Test Bed**
  - Focus Area 6: Precise 4-D Trajectories & Negotiation
- **Why Departure TFM using 4D Trajectories?**
  - Departure Release Problem
- **Departure TFM Experiments**
  - Four Phases of Development
- **Phase I Experiment**
  - Departure FMS Trajectory Study
- **Phase II Development**
  - Decision support tools for Departure Release
    - Basic En Route Departure Advisor (ERDA) functionality to assist TMC

NextGen ATS CNS Test Bed

Real World Environment For Proving Technical Feasibility And Operational Viability

- **Secure network of new sensors (e.g., ADS-B, NexGen Multilateration) and existing NAS infrastructure, connected via wireless, datalink communications**
- **"Operations" center with displays, information hub and interfaces to existing NAS infrastructure**
- **Publish/subscribe data distribution & access via SWIM/SDN architecture**
- **Participating aircraft with test instrumentation**



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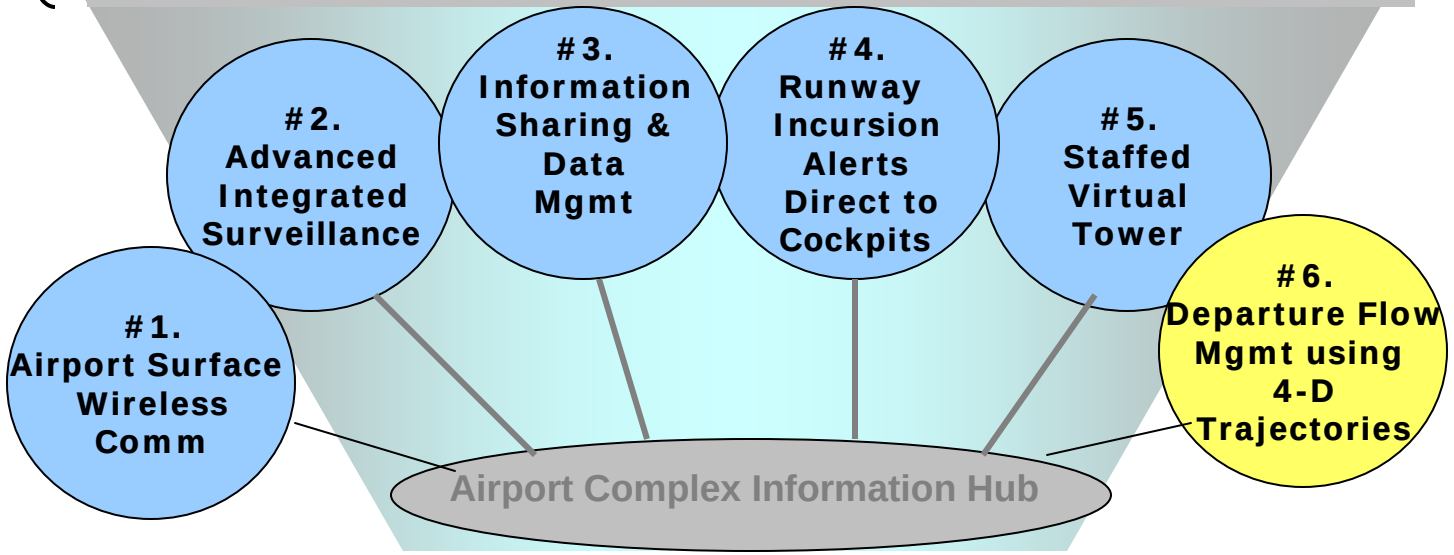
1st Two Years Focuses on Six Advances

Key NAS Transformation Capabilities Per JPDO

- Network Enabled Information Access
- Assimilation Of Weather Into Decision Making
- Broad Area Precision Navigation
- Equivalent Visual Operations
- Performance Based Services
- Layered, Adaptive Security
- Trajectory-Based Operations
- Super Density Operations

Cleveland NextGen ATS Test Bed Initial Focus Areas



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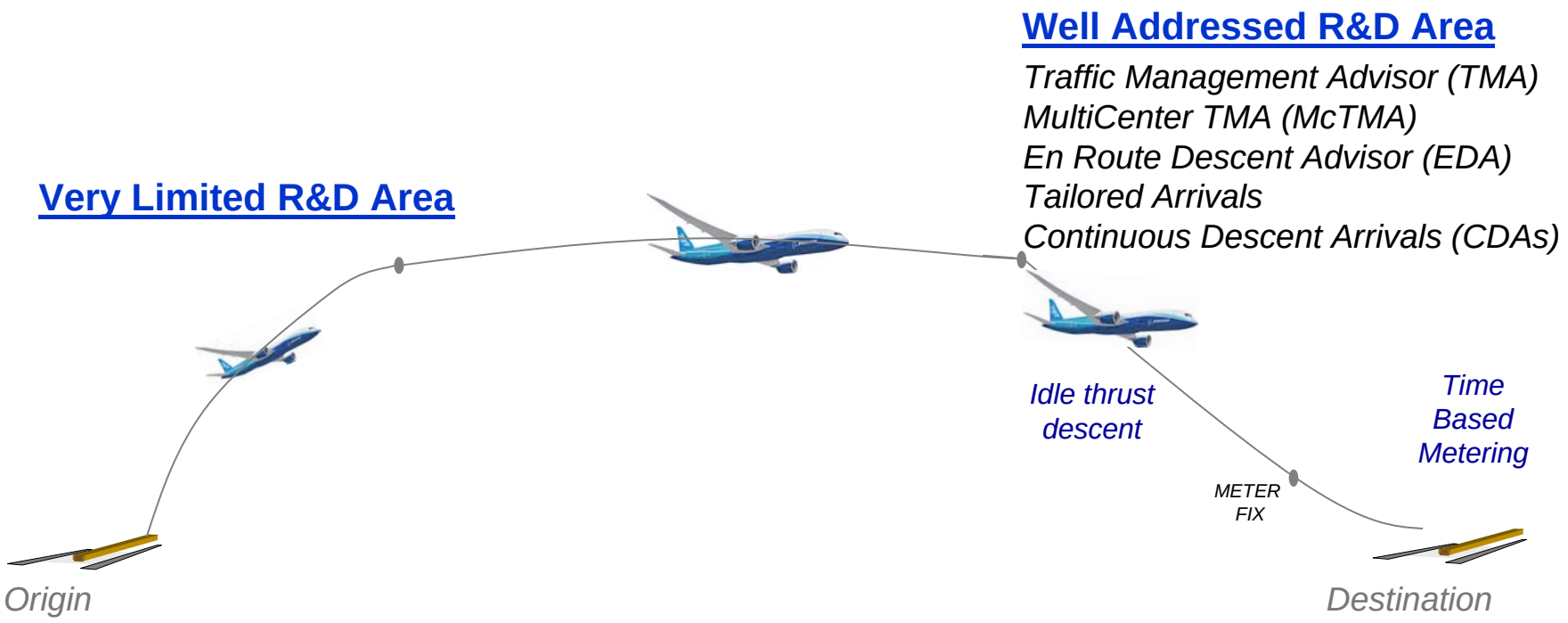
Why Focus on *Departures* Using 4D Trajectories?

- **Arrivals have been focus of most previous 4D R&D efforts**
- **Departure R&D minimal, but needed for full 4D realization**



Why Focus on *Traffic Flow Management* Using 4D Trajectories?

- **TFM functions provide best opportunity to demonstrate and evaluate 4D trajectories in near-term real world applications**
- **Can demonstrate improved accuracy and predictability using 4D trajectories of individual aircraft without safety implications of ATC "separation assurance" functions**
- **Real world TFM experience provides the foundation for 4D trajectory applications beyond TFM**

Current Departure Release Process

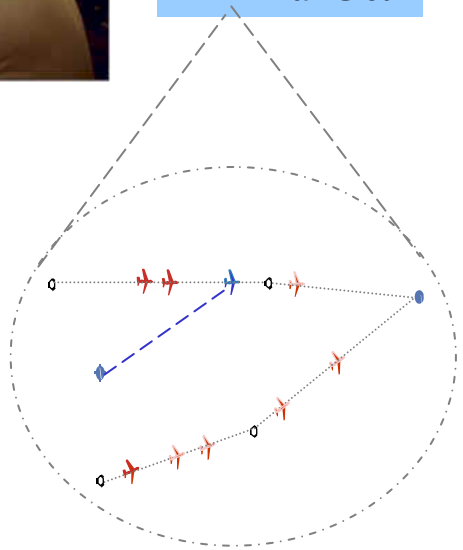
ATCT TMC

ARTCC TMC

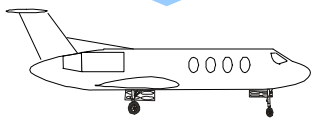
1 - Call for Approval Request (APREQ) Release Time & Report Earliest Takeoff Time (voice)

3 - Approve APREQ and provide APREQ Release Time (voice)

2 - Determine Takeoff Time to Fit Aircraft Into Appropriate TFM Plan Slot



4 - Provide Aircraft Clearances to Hit APREQ Release Time



Areas for Improvement:

- Inefficient process due to congestion on voice frequency
- Handling multiple simultaneous requests is a challenge (e.g., - telephones not answered)
- Quality of estimate is dependent on the TMC's ability to estimate taxi time and 4D climb trajectory – quality will vary
- Variability in the quality of estimates in aircraft takeoff times and climb trajectories can result in poor TFM slot adherence precision – translates into aircraft being manipulated by ATC to fit into en route flow

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Enhanced Departure Release Process

Enhanced comm/display system eliminates voice comm for APREQ process

ATCT TMC

ARTCC TMC

Departure Release Communication System (DRCS)

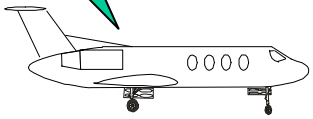
Landline Data

Air Traffic Control Tower – Departure Tool (ATCT-DT)

Automation tool to assist Tower in estimating taxi out time

Automation tool to assist TMC in identifying specific slot (based on MIT or time based metering) in en route flow and translating to APREQ time using the user-optimized trajectory

Wireless Datalink



En Route Departure Advisor (ERDA)

FMS Generated Departure Trajectory

4D-FMS

User optimal departure trajectory sent to ATC to incorporate into APREQ planning

Benefits of Enhanced System:

- *Speeds up APREQ process*
- *Increases accuracy and predictability of APREQ and aircraft trajectory prediction to en route flow*
- *Reduces ATC workload*
- *User optimized trajectory included in ATC planning increases probability that aircraft will actually fly the user optimized trajectory without ATC interference*

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Four Phases of Development

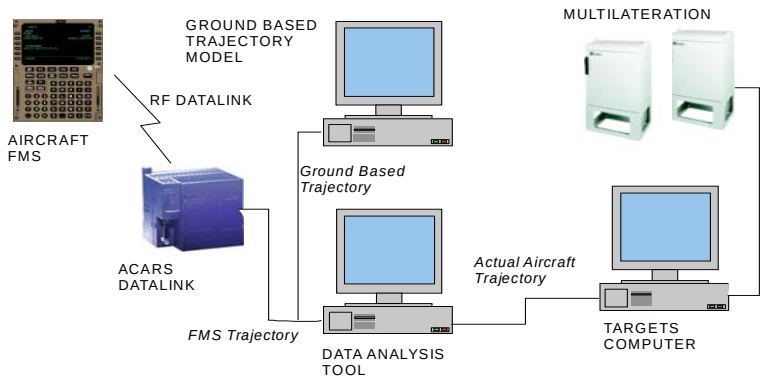
- **Phase I: Departure FMS Trajectory Prediction Analysis**
  - Collect FMS predicted trajectory before aircraft departs
  - Predict trajectory using ground based tools
  - Track actual flights and compare to predicted trajectories
- **Phase II: Initial ARTCC Prediction Tool Tailored to assist TMU**
  - Termed: En Route Departure Advisor (ERDA)
  - Near term viability for 4D technologies
  - Assists with TFM departure planning
  - Uses 4DT for estimating departure aircraft trajectory
- **Phase III: Integrated ATCT-ARTCC Departure Clearance Negotiation**
  - Phase I & II plus web based communication between center and tower personnel
  - Based on NASA Ames DRCS tool
- **Phase IV: Integrated Surface-Airborne Prediction and Clearance Negotiation**
  - Predicts expected wheels-up, earliest wheels-up, and necessary push back times
  - Provides full-up, integrated system

Phase 1

4D Departure Experiment

- **Track actual aircraft departure trajectories**
  - Uses multilateration, radar and ADS-B surveillance
  - Collect surface movement information
- **Downlink FMS departure trajectory prediction**
  - Uses ACARS datalink
- **Generate ground based trajectory prediction**
- **Compare three different trajectories**
  - FMS predicted
  - Ground computed
  - Actual tracked

- **Cleveland is ideal location**
  - Continental Airlines Partnership
  - All Continental 737 maintenance is done there
  - 13 Continental 737s already have ADS-B equipment
  - Continental does its pilot training at Cleveland



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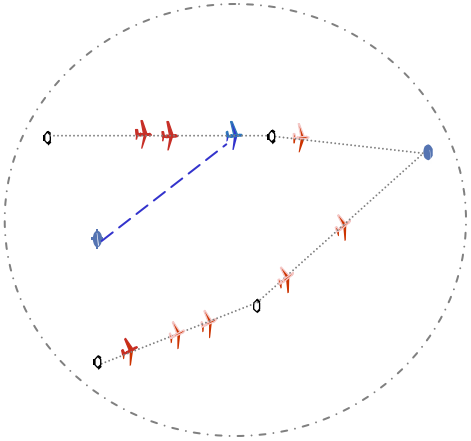
Phase 1 4DT Experiment Details

- **Goals**
  - Evaluate FMS 4D departure trajectory prediction performance
  - Evaluate ground-based 4D trajectory prediction performance
  - Estimate potential fuel savings
- **Operational Scenario**
  - Select 737 test flights operating during low density operations
  - Prior to departure, aircraft FMS aircraft uploads wind data for departure trajectory
  - Aircraft downloads FMS departure prediction via ACARS (to AOC or other designated source)
  - Aircraft flies departure using FMS to en route cruise altitude; ATC gives aircraft unimpeded departure trajectory when practical
- **Number of Participating Flights**
  - Current estimate is 200 desired (100 baseline and 100 test)
  - Number to be verified once success rate can be estimated (with ATC)
  - Time frame is TBD by availability of flights and ATC determination of acceptable candidate flights

Phase 2

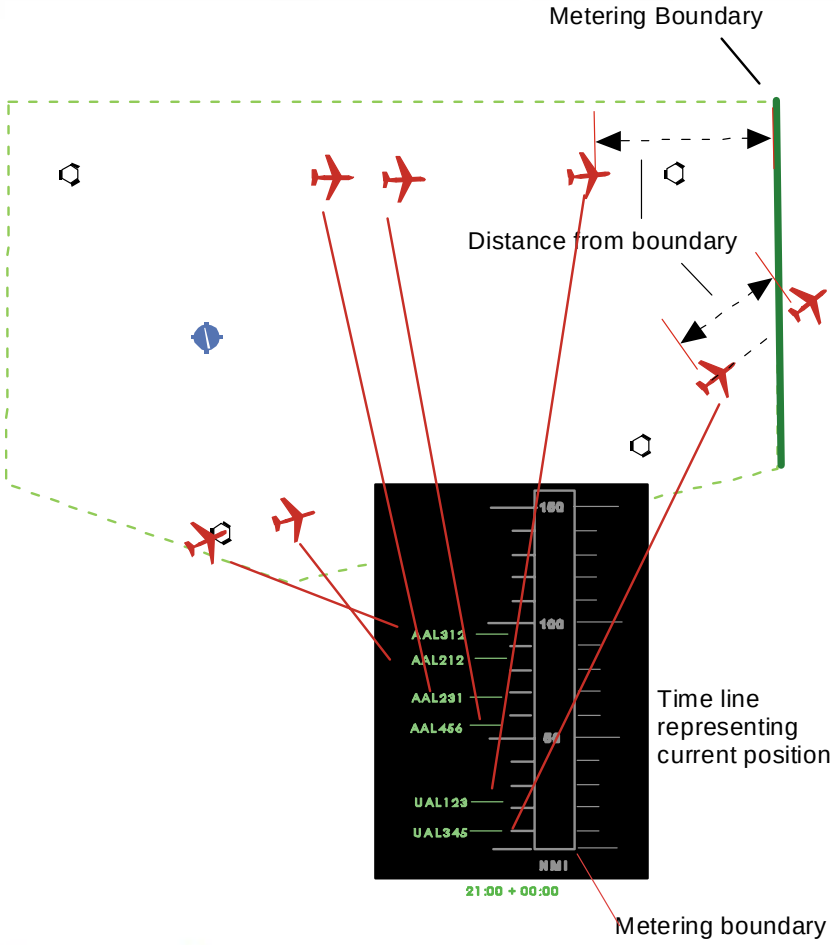
En Route Departure Advisor (ERDA)

- **Develop Prototype ERDA**
  - Tailored to assist TMU
  - Near term viability for 4D technologies
- **Assists with Miles-in-trail Spacing**
- **Uses FMS Based Trajectories for Estimating Departure Aircraft Position**
- **Supports Non-FMS Equipped Aircraft**
  - Internal modeling capability
- **Run Operational Tests at Cleveland Center**



En Route Departure Advisor (ERDA) Solution

- **Relate aircraft position on range lines**



Current Position Range line

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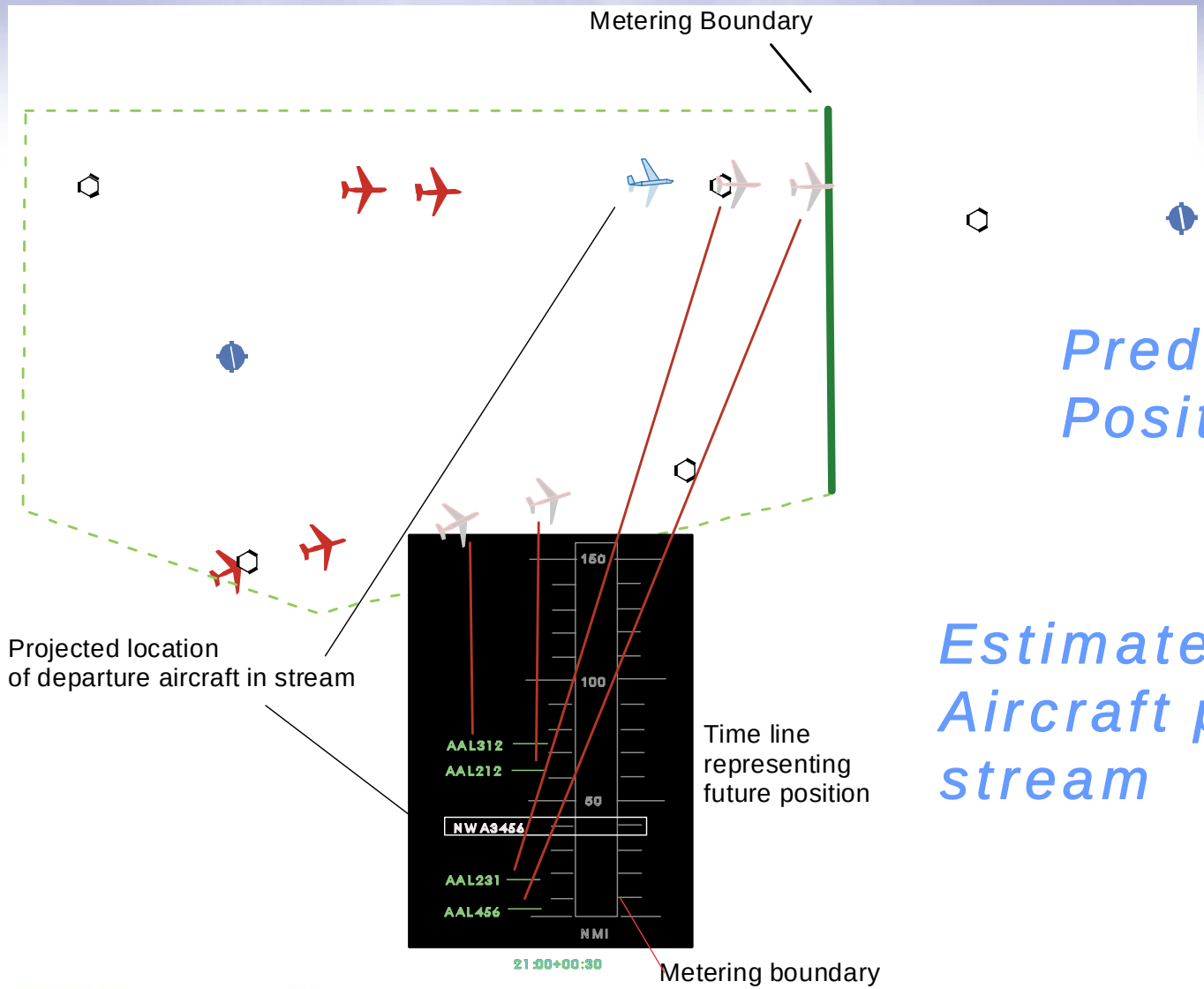
En Route Departure Advisor (ERDA) Solution



Predict Future Positions

Estimate Departure Aircraft position in stream

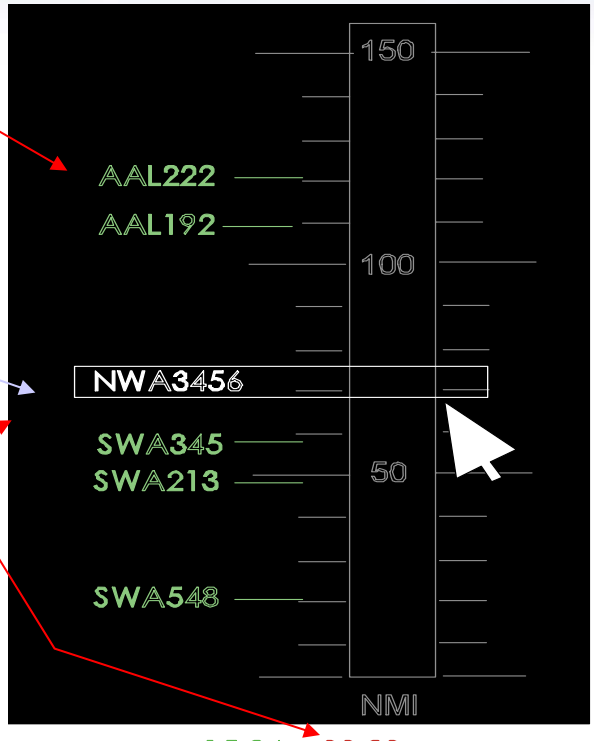
En Route Departure Advisor (ERDA) Solution

- **FMS calculated climb trajectories provide climb prediction**
- **Ground based tool to identify gaps**

Predicts aircraft location 30 minutes in the future

Identifies departure aircraft location in stream

Based on FMS trajectory



Why This and Why Now?

Why this set of experiments?

- **4D gate-to-gate trajectories are a foundational concept for NextGen**
  - Great opportunity to explore this key component
- **Departure process hasn't received same level of attention as arrival process**
- **Ability to utilize existing HW on aircraft makes it practical**
  - Can utilize existing capabilities on Smiths FMS equipped aircraft to support initial 4D trajectory departure planning ConOps
- **Ability to utilize existing HW / SW as starting point for automation makes it doable in the near-term**
- **Relative ease in incorporating enhancements into the existing ATC / ATM operational environment**
- **Getting real world experience early will help flesh out key operational constraints to minimize time-to-initial operating capability**
  - Early and frequent exposure of new concepts to operational domain has been a hallmark of previous NASA and FAA successes
- **Starting 4D research focused on a single 4D en route bound aircraft avoids safety-critical issues and can offer potential benefits immediately**

Why now?

- Need to start *now* to develop and test 4D systems and procedures if we have a hope of implementing this within the next decade